NAIC-ID(RS)T-0073-96

NATIONAL AIR INTELLIGENCE CENTER

NATURAL RESOURCE SATELLITE NO. 1 IMAGERY PREPROCESSING GEOMETRICAL CALIBRATION METHOD

by

Yu Jin

Approved for public release: distribution unlimited

NAIC-ID(RS)T-0073-96

HUMAN TRANSLATION

NAIC-ID(RS)T-0073-96 2 April 1996

MICROFICHE NR: 96C000291

NATURAL RESOURCE SATELLITE NO. 1 IMAGERY PREPROCESSING GEOMETRICAL CALIBRATION METHOD

By: Yu Jin

English pages: 7

Source: Cama, China Astronautics and Missilery Abstracts, Vol. 1, Nr. 5, 1994; pp. 52-55

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: NAIC/TASR/Mark Shockey
Approved for public release: distribution unlimited.

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

It is projected that, within the next few years, China will launch its first natural resource satellite (ZY-1 satellite). Satellite and ground reception as well as data processing application systems also follow it, beginning preparations for construction. Satellite data preprocessing is an important subsystem in ground application systems. Preprocessing technology is basically weak in China. Beginning the development of research associated with preprocessing geometrical correction algorithms for ZY-1 satellite products is very necessary.

I. ZY-1 SATELLITE IMAGERY GEOMETRICAL CHARACTERISTICS

ZY-1 satellites operate in near circular solar synchronous orbits. Their main useful load is CCD cameras and IR-MSS scanning devices. They are capable of separately obtaining multiple spectrum imagery of the earth. CCD cameras also possess panchromatic wave band imagery. Its various wave bands are all 6000 image point. In vertical observations, ground resolutions are 19.4m. IR-MSS scanning devices are 1536 image point. Ground resolution is 78m. CCD camera directional lenses permit side views on the two sides of orbits deviating from the nadir. In space--perpendicular to orbital direction--using 2' interval partially blocked slopes, maximum side view angles are ±32°. ZY-1 satellite control system attitude assurance error < 0.15°.

CCD camera form is central projection. At a certain instant (that is, x=0) the expansion derived for form equations is:

$$\begin{cases} (x):\ 0 = -f\dfrac{a_{11}(x_p - x_s) + a_{21}(y_p - y_s) + a_{31}(z_p - z_s)}{a_{13}(x_p - x_s) + a_{23}(y_p - y_s) + a_{33}(z_p - z_s)} \\ (y):\ y = -f\dfrac{a_{12}(x_p - x_s) + a_{22}(y_p - y_s) + a_{32}(z_p - z_s)}{a_{13}(x_p - x_s) + a_{23}(y_p - y_s) + a_{33}(z_p - z_s)} \end{cases}$$

In this, f--camera primary length; x,y--image coordinates in sensor coordinate system; a11, a12, ..., a33--attitude angle rotation matrix coefficients; x_p, y_p, z_p --ground coordinates of target points; x_s, y_s, z_s --coordinates of points under satellite.

IR-MSS infrared scanning instrument geometrical form is a panoramic projection as time x=0. The corresponding structural equations are:

$$\begin{cases} (x):\ 0 = -f\dfrac{a_{11}(x_p - x_s) + a_{21}(y_p - y_s) + a_{31}(z_p - z_s)}{a_{13}(x_p - x_s) + a_{23}(y_p - y_s) + a_{33}(z_p - z_s)} \\ (y):\ f \cdot \mathrm{tg}\theta = -f\dfrac{a_{12}(x_p - x_s) + a_{22}(y_p - y_s) + a_{32}(z_p - z_s)}{a_{13}(x_p - x_s) + a_{23}(y_p - y_s) + a_{33}(z_p - z_s)} \end{cases}$$

In this, θ--scanning angle.

II. ZY-1 SATELLITE IMAGERY DEFORMATION ERRORS

ZY-1 satellite imagery deformations can be roughly divided into two classes--internal errors and external errors. Interior errors are given rise to by the structural characteristics of/53 sensor devices becoming nonideal or their indices deviating from nomimal numerical values--for example, standardized primary camera lengths being different from the actual ones; noncontinuity of surface features on imagery given rise to by bidirectional scanning errors associated with multiple spectrum scanning devices; the existence of such phenomena as intersections, omissions, as well as overlaps between image elements and scanning lines, and so on, and so on. Among these errors, systemic ones should go through sensor device inspections in order to be calibrated or be given correction formulae to supply to processing systems for corrections. As far as external errors are concerned, that is, sensor device errors with respect to positioning during imagery processes, they primarily include the several types below.

1. Changes in Sensor Device External Azimuth Elements

With regard to the analysis of the deformation errors in question, it is possible to carry out differentiation in respect to the two ends of collinear sensor equations by directional displacements associated with the coordinates x,y,z of points under satellites and the three sensor attitude angles ψ , ω, κ being variables. One obtains:

$$\begin{cases} dx = \frac{\partial x}{\partial x_s} dx_s + \frac{\partial x}{\partial y_s} dy_s + \frac{\partial x}{\partial z_s} dz_s + \frac{\partial x}{\partial \psi} d\psi + \frac{\partial x}{\partial \omega} \partial\omega + \frac{\partial x}{\partial K} dK \\ dy = \frac{\partial y}{\partial x_s} dx_s + \frac{\partial y}{\partial y_s} dy_s + \frac{\partial y}{\partial z_s} dz_s + \frac{\partial y}{\partial \psi} d\psi + \frac{\partial y}{\partial \omega} \partial\omega + \frac{\partial y}{\partial K} dK \end{cases}$$

Again, on the basis of sensor structural equation rotation matrices, it is then possible to derive the image point displacement formulae given rise to by dx, dy, dz, dψ, dω, and dK.

2. Imagary Errors Given Rise to by the Spin of the Earth

When ZY-1 satellites make scanning movements from north to south, due to the earth, there is also a spinning from west to east at the same time. As a result, the loci of points under the satllites gives rise to a bending and sloping toward the west. Simultaneously, because the geographical latitudes associated with points under satellites are different, the linear velocities

associated with the spinning earth VE at the locations in question are also different. As a result, errors given rise to are capable of going through corrections, solving for transverse displacement values dyω of any scanning line in an image relative to the first scanning line and the average image deflection angle θy .

3. Image Deformations Given Rise to by the Curvature of the Earth

With regard to the influence of the curvature of the earth, it is possible to make use of height differences Δh given rise to by the earth's degree of curvature, which exist for images projected on a spherical reference system, or to make use of points on the ground relative to projection planes, deriving imagery earth curvature image point displacement formulae and applying corrections.

III. ZY-1 SATELLITE IMAGERY GEOMETRICAL CORRECTIONS

As far as ZY-1 satellites opting for the use of digital imagery is concerned--with regard to imagery geometry calibrations carried out in association with imagery errors given rise to because of satellite orbital deviations and sensor attitude changes--on the basis of digital correction models, it is possible to distinguish "reference methods" and "nonreference methods". Parameter methods primarily refer to colinear equation methods. Nonreference methods mostly indicate multiple term type correction methods as well as random field interpolation value methods, and so on. General processes associated with digital correction methods are as shown in Fig.1.

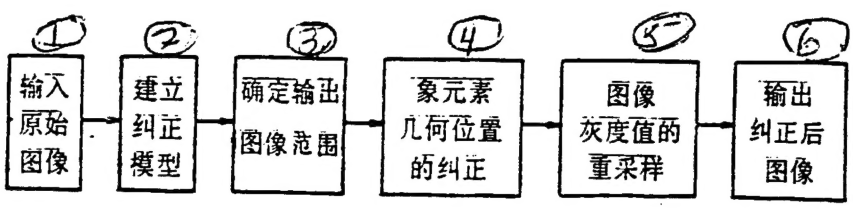

Fig.1 (1) Input Original Pattern (2) Set Up Correction Model (3) Precisely Determine Output Pattern Range (5) Correction of Image Element Geometrical Positions (6) Resampling of Pattern Greyness Values

Satellite imagery geometrical correction preprocessing normally is also divided into rough processing and precision processing. Rough processing generally indicates making use of a number of geometrical parameters which can be predicted during imagery formation processes, associated with scanning images, in

order to directly construct correction formulae and carry out calibrations. As far as comparisions between precision processing and rough processing are concerned, the differences are that /54 precision processing requires making use of ground control points to act as correction bases. On the basis of requirements associated with the "Overall Plan for Natural Resources No.1 Satellite Application System Technology", ZY-1 satellite imagery products are divided into 6 levels:

0 Level: Divided amplitude data products which have not undergone any calibration
1 Level: Products Having Undergone Radiation Calibration
2 Level: System Level Geometrical Calibration Products
3 Level: Two Dimensional Geometrical Calibration Products Using a Series of Ground Control Points as a Foundation
4 Level: Products Making Use of Ground Elevation Models to Act as Geometrical Corrections
5 Level: High Level Nonstandard Products

The large amounts of ZY-1 satellite preprocessing products should be divided into the two classes of imagery products. Besides this, based on user requirements, use is made of small numbers of ground control points to act as a third class of batch precision processing products. With regard to more advanced precision processing products, users need not directly make use of such supplementary data as satellite orbits, attitudes, and so on, using polynomial equations for autonomous processing or requiring special processing by processing centers.

Level 2 ZY-1 satellite products directly make use of satellite orbits, sensor attitude data, and structural equations based on sensors to construct geometrical correction formulae to carry out corrections. As far as the actual situations given rise to by the combined factors of unknown attitude errors and errors associated with orbits announced in advance are concerned, mean square deviations associated with predeterimed views should be within a range of 800m.

With respect to ZY-1 satellite imagery level 2 products, the methods of geometrical correction based on different sensors are as follows.

1. IR-MSS Scanning Device Imagery Product Rough Processing

Based on experience associated with the U.S. Landset satellite, ZY-1 satellite imagery is capable of separately supplying users--after opting for the use of two types of correction methods--with level 2 products.

(1) Slope Elimination Corrected Products

To primarily carry out corrections of errors associated with imagery distortion, single event expansions and contractions, and deflection deformations given rise to by such factors as the spin of the earth, image element x and y direction dimensions not being equal, as well as satellite orbital plane deflection angles (that

is, the angles included between the axses of spin of the earth), and so on, the formula is:

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & M_y \end{bmatrix} \begin{bmatrix} \cos\alpha & \mathrm{Sin}\alpha \\ -\mathrm{Sin}\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \theta_y & 1 \end{bmatrix} \cdot M_o \begin{bmatrix} x' \\ y' \end{bmatrix}$$

In this, x,y--original imagery coordinates associated with a certain image element; x',y'--corrected imagery coordinates associated with the corresponding image element; My--ZY-1 satellite imagery aspect ratio; α--satellite movement direction angle; θy--mean imagery distortion angle; Mo--rotation matrix associated with imagery top level after making corrections.

(2) Map Projection Correction Methods

The principle is that one first defines an image grid on the original imagery. Making use of sensor device movement parameters that can be predicted, one uses grid point coordinates, converting them into geographical latitude and longitude in accordance with colinear equations. Going a step further, they are converted to map projection system coordinates, using grid lattice points to act as artificial control points in order to calculate a set of corrected polynomial coefficients. Then, calibrations are carried out on the basis of polynomials for all points with respect to the imagery. As far as concrete algorithms are concerned, it is possible to opt for the use of simplified, high speed algorithms.

2. Rough Processing of CCD Camera Level 2 Product

Defining satellite height changes as dzs, define photography station translations given rise to by satellite speed changes as dxs and dys. Defining camera directional lens positioning errors as dψ and dω, it is possible to construct image point displacement formulae, carrying out corrections with respect to errors given rise to by external azimuth elements.

With regard to the influences of the curvature of the earth, it is possible to take imagery and project it onto spherical shaped reference systems and achieve corrections.

The influences of the spin of the earth primarily create imagery scanning line transverse displacements in the y direction and scale enlargements in the x direction. As far as translation improvements associated with ZY-1 satellite imagery are /55 concerned, it is possible to opt for the use of line by line scanning improvement methods in the same way as SPOT satellite imagery.

In regard to the contents of ZY-1 satellite CCD imagery level 2 products, the effects of such things as the undulations of terrain, sensor device attitude changes, angles of drift, and so on, are preserved. Although geometrical precision is relatively low, terrain change data is retained, however. This is

advantageous to three dimensional observations and the utilization of original terrain data.

With respect to ZY-1 satellite orbital characteristics and sensor device imagery geometrical configurations, they are respectively similar to the U.S. Landset satellite and the French SPOT satellite. Therefore, in making use of satellite prediction parameters to carry out rough processing associated with geometrical preprocessing--in terms of the principles of processing--they are the same as the foreign satellites. In computer software algorithms and software writing, design will be autonomous.

As far as geometrical calibration of ZY-1 satellite level 3 product is concerned, it is possible to make use of simplified correction models--for example, opting for the use of planar grid distortion model interpolation methods or other high speed algorithms, making use of as few ground control points or ground control point imagery banks as possible to carry out corrections.

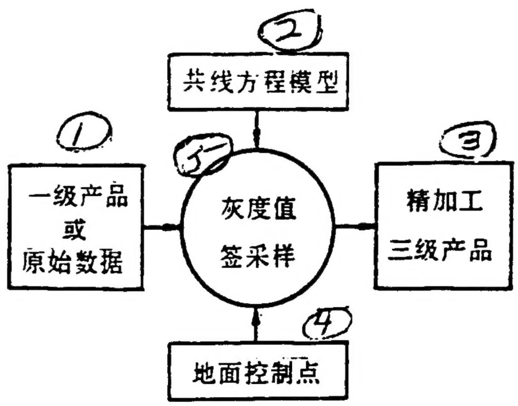

Fig.2 (1) Level 1 Product or Original Data (2) Colinear Equation Model (3) Precision Processing Level 3 Product (4) Ground Control Point (5) Greyness Level Signature Sampling

With respect to satellite imagery geometrical corrections--after conversion of geometrical positions--there is generally a need in all cases to carry out sampling of imagery greyness values again. During previous satellite imagery preprocessing--on a foundation of roughly calibrated products--further precision processing is generally always done. For example, each level of product associated with the French SPOT satellite imagery is a reprocessing into higher level products. In this way, precision processed products will all go through several interations of greyness value resampling. Although option is made for the use of interpolation prinicples in order to reduce greyness level drops, due to multiple iterations of greyness resampling, however, imagery greyness levels are still created which must necessarily go down.

In order to escape from this, the three levels of ZY-1 satellite products should--from satellite level 1 imagery products and not making use of level 2 products--go through calibration

models and ground control points. In conjunction with this, methods used produce precision processing products one time. The method flow chart is seen in Fig.2.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE
B085 DIA/RTS-2FI	1
C509 BALLOC509 BALLISTIC RES LAB	1
C510 R&T LABS/AVEADCOM	1
C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
Q592 FSTC	4
Q619 MSIC REDSTONE	1
Q008 NTIC	1
Q043 AFMIC-IS	1
E404 AEDC/DOF	1
E410 AFDTC/IN	1
E429 SD/IND	1
P005 DOE/ISA/DDI	1
1051 AFIT/LDE	1
P090 NSA/CDB	1

Microfiche Nbr: FTD96C000291
NAIC-ID(RS)T-0073-96